DETERMINATION OF STOL AIR TERMINAL TRAFFIC CAPACITY THROUGH USE OF COMPUTER SIMULATION

ROBERT EVANS RINKER

United States
Naval Postgraduate School

THESIS

DETERMINATION OF STOL AIR TERMINAL
TRAFFIC CAPACITY THROUGH USE OF
COMPUTER SIMULATION

by

Robert Evans Rinker

Thesis Advisor: A. F. Andrus

September 1971

Determination of STOL Air Terminal

Traffic Capacity Through Use of

Computer Simulation

by

Robert Evans Rinker
Lieutenant, United States Navy
B.S., United States Naval Academy, 1964

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1971

ABSTRACT

The capacity of an air terminal for Short Takeoff and Landing aircraft is analyzed. The terminal is considered to be operating as part of an intra-urban air rapid transit system. The air traffic flow through the terminal is modeled by a computer simulation written in both the FORTRAN IV and GPSS languages. The model is used to solve the traffic capacity problem under two sets of traffic control rules. In the first case, existing FAA rules, which require 3 miles separation between arrivals and 2 miles between an arrival and a departure, are used. In a second case, the rules are 2 miles between arrivals and 1 mile between an arrival and a departure. A detailed description of the model is presented so that others might use the model.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE

I. INTRODUCTION

One of the many problems facing our cities today is the lack of effective and economically feasible rapid transit systems. Solutions to this problem cannot be thought of in terms of today's hardware and technology because of the long lead time required for development of complex rapid transit systems. In fact, today one must consider systems for operation five or ten years in the future.

One system that is currently being examined is based on the use of Short Takeoff and Landing (STOL) aircraft in this very short haul intra-urban market. This type of transportation system may be suitable for an urban area such as the San Francisco Bay area. It would complement rather than replace existing systems, such as San Francisco's BART. To the extent possible, the STOL system would use existing facilities. Where no air terminals now exist, such as in downtown San Francisco, terminals would be built especially for the STOL system.

The system is envisioned to operate more like a bus line than an air line. There would be no cabin attendants and stops at terminals would be a matter of minutes instead of hours. Only one basic type of aircraft would be used and the system would be operated under a local monopoly, probably by a municipally owned company.

The National Aeronautics and Space Administration has initiated both in-house and contract studies of the STOL rapid transit system.

NASA examined the economics of the system [1], and the system was found to be economically feasible. Reassured that the idea had merit, NASA let contracts for a detailed system design to the Boeing corporation. The Boeing study proposed an aircraft to be used in the system and a terminal design and placement scheme. [2] The STOL port proposed had a single runway with multiple passenger gates. It was to be used only by the STOL system with no other traffic allowed.

Boeing performed an economic analysis of their system proposal and found it to be economically feasible under the proper assumptions. The critical economic areas were the fixed costs of construction and operation, and the costs of unproductive ground and holding pattern time of the aircraft. [2] All of these costs are directly related since a greater amount of unproductive aircraft time requires more aircraft to satisfy a given demand than would be required if the unproductive time were short. The higher number of aircraft would require more terminal facilities to handle them. The cost of having to obtain and operate the increased number of terminals and aircraft could make the system economically unsound. Thus it is important to have both aircraft and terminals operating efficiently to minimize the number of each required to operate the system.

II. STATEMENT OF THE PROBLEM

The matter of facility capacity seems to be an important key to the potential success of the system. This paper presents the development of a model which can be used to determine STOL terminal traffic capacity in the context of the rapid transit system described above.

Given a particular set of assumptions, a measure of capacity will be defined and capacity determined under two sets of traffic control rules. The two solutions will be made to demonstrate the effect on capacity of allowing reduced aircraft separation.

First the problem will be solved using existing FAA traffic separation rules of 3 miles between consecutive arrivals and 2 miles between an arrival and a departure. The problem will then be solved using separation requirements of 2 miles between consecutive arrivals and 1 mile between an arrival and a departure. This latter set of separation requirements reflect rule changes that may result from the use of more precise navigation and air traffic control equipment.

III. SOLUTION TECHNIQUE

The economic success of the STOL rapid transit system depends heavily on the rapid and efficient cycling of aircraft through the terminals. The consequences of an inaccurate capacity figure therefore make an educated guess, or trial and error solution, unacceptable, since long aircraft delays caused by overloaded terminals or idle facilities caused by under utilized assets would prove disasterous to the system budget.

Computer simulation was chosen as the solution method in light of the necessity of a solution and the obstacles posed by direct analytical techniques. The interdependencies between various events in the system would make direct solution an impossible task. If the dependencies and distributions involved were simplified to the point that direct mathematical solution was possible, the model resulting would probably be only a gross representation of the system.

The simulation model described in the following sections was used in the problem solution. Five hours of simulated time were simulated to examine the period covering evening rush hour, this being the time of heaviest traffic. The model was run for two hours of simulated time at 1/2 peak flow. The traffic flow rate was then increased over a period of 90 minutes to peak flow and held there for one hour of simulated time. The model then simulated another 30 minutes at a traffic flow of 1/3 peak.

Data was examined for the final 3 hours of the 5 simulated hours. The peak flow was adjusted until the traffic capacity was found. The criterion used to define capacity was the expected delay time for those aircraft which had to wait to start their approach. This was estimated using the average holding pattern time. When the expected delay time for those aircraft that had to wait reached 3 minutes, the airport was considered to be at capacity. This admittedly somewhat arbitrary criterion was chosen because it represents the author's opinion of the maximum amount of time a traffic controller could be expected to be able to delay an arrival by indirect routing - hence it is the point at which an arrival would have to enter a holding pattern.

IV. ASSUMPTIONS

A. LIST OF ASSUMPTIONS

The assumptions that were made in the solution of the problem were:

1. The aircraft involved is a multi-engine STOL aircraft with fast load/unload capability.

2. The aerodynamic stall speed is 60 MPH in the landing configuration.

3. The speed the aircraft flies on the approach is normally distributed with mean 82.3 MPH and standard deviation of 5.04 MPH.

4. The landing speed is normally distributed with mean 77 MPH and standard deviation 4.25 MPH.

5. The aircraft decelerates after landing at a constant rate of 10 ft/sec^2 until a speed of 10 MPH is reached. At that time, the aircraft turns off the runway and is clear in 5 seconds.

6. The distribution of time between arrivals is exponential and all arrivals are independent.

7. Taxi time between the runway and the gates is 1.5 minutes for arrivals and departures.

8. Gate time is exponentially distributed with a mean of 3 minutes.

9. The time required to position the aircraft in position for take-off on the runway is .25 minutes.

10. The take-off is modeled as a constant acceleration from a standing start at the rate of 10 ft/sec^2, until a speed of 77 MPH is reached.

11. The terminal has an approach course that is 9 miles long.

12. 13 miles must be flown back to the start of the approach course if a go-around (or wave-off) is necessary.

13. The aircraft is capable of executing a safe wave-off from any point on the approach course greater than 0.1 miles from the landing point.

14. The terminal is equipped with 3 passenger gates.

15. The weather is good with no wind.

B. JUSTIFICATION OF ASSUMPTIONS

This section is included to explain the reasons for the assumptions made in the problem solution.

1. The aircraft was modeled after the proposal made by the Boeing corporation. [2]

2. The speed distributions for both the approach speed and landing speed were based on a study of speed distributions of present day passenger jets [3], and the premise that the STOL aircraft will be able to be flown as consistently near designed approach speed as present day commercial aircraft. There is reason to believe they will in fact be easier to fly than today's jets.

3. The inter arrival time assumption is based on studies of actual arrivals at commercial airports [4, 5, 6]. One may doubt the validity of drawing an analogy between contemporary commercial airports, with many independent (in the statistical sense) airlines, and the one company STOL port. However a parallel situation does exist. Instead of different airlines, we have aircraft on different routes in the system. If one considers each route as a different line, the exact same traffic situation exists at the STOL port and a commercial air port.

4. The gate time distribution assumption is based on the characteristics of similar types of short stop systems [4].

V. SENSITIVITY ANALYSIS

This section is included to indicate the sensitivity of the solution to the assumptions made.

The speed distribution assumption is conservative. The previous section indicated that the normality assumption would probably result in speeds more variable than would actually exist. This is stated to be conservative because a smaller variation in speeds than that assumed would result in a larger peak flow at capacity. This happens because the traffic separation is attained at the start of the approach. If two consecutive arrivals have different approach speeds and the faster one follows the slower one, the second may be too close behind the first at landing. If this happens, the first aircraft will not be clear of the runway and the second will have to go around.

The solution is entirely dependent on the mean approach speed assumed. Since the separation required is specified as distance between aircraft (rather than time between aircraft), aircraft with faster approach speeds will be able to attain this distance in less time than slower aircraft. The wind plays a role in this also, since the ground speed actually determines the time needed to get the required spacing. An indication of the effect of ground speed can be seen by noting that the time needed to get the approach separation is a linear function of the ground speed. At the assumed ground speed of 82.3 MPH, a capacity of

22 aircraft per hour can be handled using the 3 mile separation rule. Applying the ratio of peak flow to speed, one can predict a peak capacity of 24 aircraft per hour at a speed of 92 MPH, and 19 per hour at 72 MPH.

The selection of the landing speed and deceleration assumption become critical only when the time required for an aircraft to clear the runway after landing is so great that there is no opportunity to insert a departure between two arrivals. Naturally the amount of time required for a departure is as important as the time needed for a landing. The time needed for a departure to taxi into position for takeoff is not critical since this can be done while the previous arrival is decelerating. What is required then is that the time between arrivals be such that a deceleration from landing speed to taxi speed and an acceleration to takeoff speed can occur. Looking at the mean speeds involved, we find that a landing followed by a takeoff takes about 25 seconds. The average time between arrivals (using 2 miles separation and 82 MPH) is 88 seconds. There is obviously a lot of slack time available, which means that the landing and takeoff procedures are not critical to the flow rate.

Taxi time has no effect on the waiting time and simply adds on to the total cycle time. Thus as far as the capacity of the terminal is concerned, the taxi time is really immaterial.

The gate time could have an effect on the solution. With the 3 minute mean time assumed, the gate queue was normally empty for all flow rates tested. Obviously, the amount of gate time available (number of gates multiplied by the time period being considered) can be such that

the gates become a bottleneck, the solution then would have to consider waiting time at the gates as well as at the holding pattern.

The weather assumption is not important. The model operates aircraft under Instrument Flight Rules. These procedures will operate the same regardless of the actual weather, unless the weather is so bad it forces closure of the terminal. It is true that bad weather results in higher landing speeds and lower deceleration rates, but since there is so much slack available in the landing and roll out phase, these longer runway times will have no effect on the solution obtained.

VI. ANALYSIS OF DATA

As has been stated, the statistic used to indicate capacity was average conditional waiting time. If this time was 3 minutes or greater the airport was considered over capacity. The model operates on the basis of abstract time units, with the interpretation in this solution being that 1 time unit equals 5 seconds. Thus the question was really to find the maximum flow rate that resulted in an expected conditional waiting time of 36 time units or less. As a preliminary step, based on the Central Limit Theorum, the assumption was made that the average conditional waiting time was distributed normally with mean equal to the true mean of the waiting time and variance unknown.

With the assumptions stated above, the following procedure was used to determine the maximum peak flow rate that resulted in a mean conditional waiting time of 36 time units or less.

1. A value of peak flow was picked and the model run for 10 replications.

2. a. If the average value of the mean conditional waiting time was greater than 36, a test of hypothesis using the 95 percentile point of the " t " distribution was made. Ho was that the true mean was less than 36, Ha that the true mean was greater than or equal to 36.

b. If the average of the mean conditional waiting time was less than 36, the test of hypothesis was made with Ho being that the

true mean was greater than 36, and Ha that the true mean was less than or equal to 36.

3. a. If Ho was not rejected, more data was taken and pooled with the previous data. The test of hypothesis procedure described above was repeated.

b. If Ho was rejected, the peak flow rate was adjusted. If the average of the sample tested was greater than 36, the peak was decreased. If the average of the sample just tested was less than 36, the peak flow rate was increased. The model was run for 10 replications at the new peak flow rate and the above procedure repeated starting at step 2.

The flow chart of Figure 1 illustrates the procedure just described. This search and test procedure was used to try to minimize the computer time needed to solve the problem. Since the actual flow rate capacity was not known within 10 increments, testing all reasonable possibilities, using a sample size large enough to insure a desired confidence level, would have been an expensive procedure. As it was, approximately 45 minutes of computer time was required to get the data that was used.

A disadvantage of this procedure is that, due to the sequential nature of the data collection and hypothesis testing, it cannot be said that the hypotheses were tested at the 95% level, even though the 95 percentile point of the "t" distribution was used to define the critical regions. Lindgren [7] presents a discussion of the problems associated with sequential sampling. The true value of the type I error in this case (the probability of rejecting a true Ho) is greater than 5%. Unfortunately,

it is probably beyond calculation. The difficulty of calculation is compounded by the fact that the sequential tests were not of the same sample size. Often a different number of data points resulted from different batches of runs. This was a phenomenon peculiar to the monitor system of the computer installation where the model was run. If the run time exceeded a certain real time limit, the run was terminated at that point.

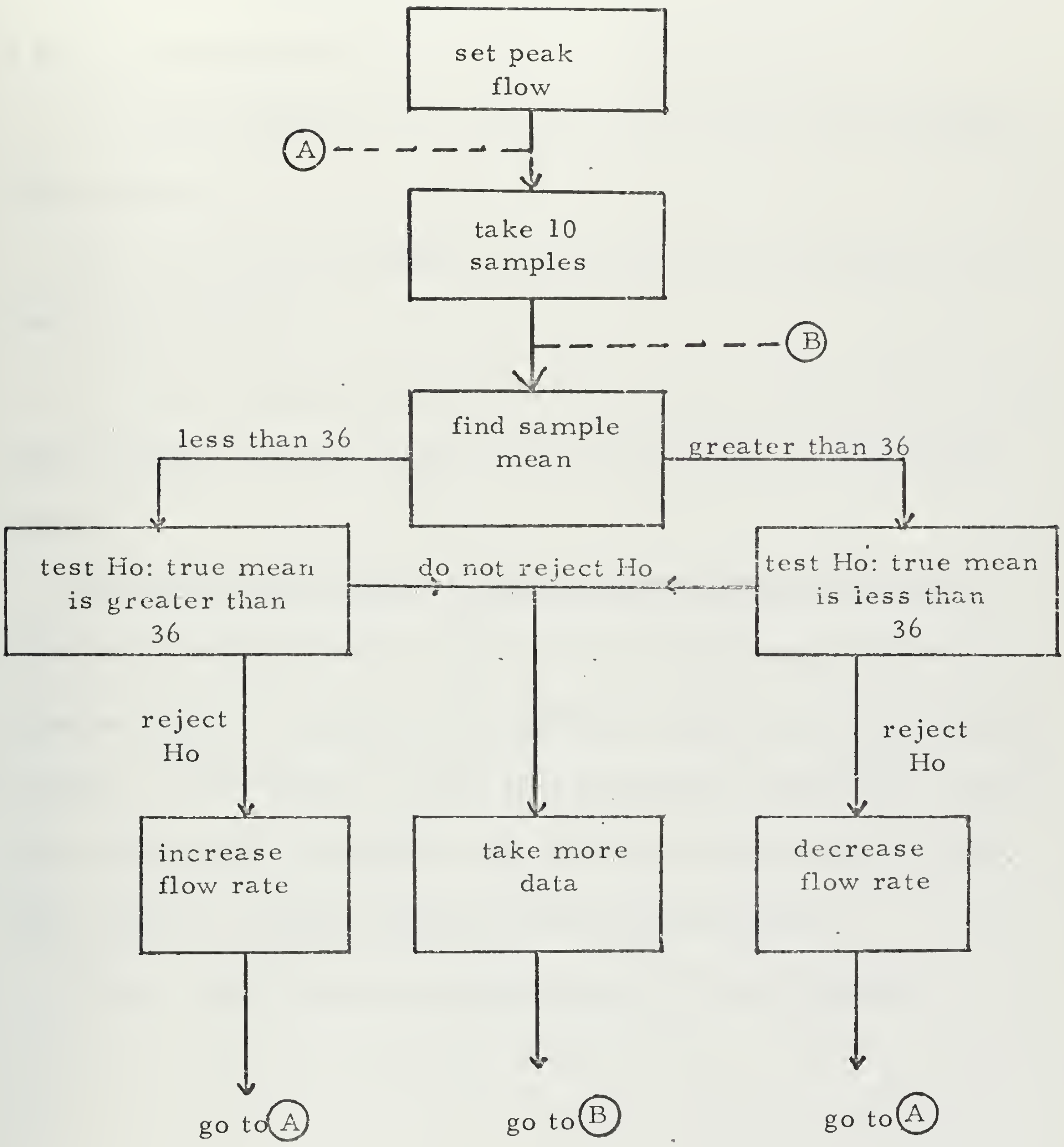


FIGURE I. ANALYSIS PROCEDURE

VII. RESULTS

The model was run under the conditions as stated. For each run of 5 hours of simulated time, the following was recorded:

1. The proportion of aircraft that did not have to wait to start their approach.

2. The average waiting time for those aircraft that had to wait to start their approach.

3. The average time for an aircraft to cycle through the terminal, measured from arrival at the start of the approach to completion of take-off.

The three sets of data were kept in hopes of finding a suitable correlation between them. The criterion decided upon to measure capacity, that is, the expected conditional waiting time, proved highly variable. Unfortunately, no precise correlation could be found which would allow the use of another measure to indicate that the desired delay limit of 3 minutes average delay had been reached.

Tables 1 and 2 contain a summary of the results obtained.

TABLE I

SUMMARY OF RESULTS

3 MILES BETWEEN ARRIVALS,
2 MILES BETWEEN ARRIVALS AND DEPARTURES

R	N	PNW	M	S	C	Hg	Hl
25	10	.28	54.10	20.21	202.76		R
24	11	.33	45.20	19.93	197.14		R
23	99	.38	39.31	21.75	187.54		R
22	105	.43	32.72	15.71	179.74	R	
21	48	.46	31.88	17.77	178.24	R	

R = Peak arrival rate in aircraft per hour.

N = Number of replications on which figures are based.

PNW = Average proportion of aircraft that did not have to wait.

M = Average conditional waiting time, in model time units.

S = The sample standard deviation of the conditional waiting time, in model time units.

C = The average cycle time, in model time units.

Hg : An "R" in this column indicates that the hypothesis "the true mean is greater than 36" was rejected.

Hl : An "R" in this column indicates that the hypothesis "the true mean is less than 36" was rejected.

TABLE 2

SUMMARY OF RESULTS

2 MILES BETWEEN ARRIVALS,
1 MILE BETWEEN ARRIVALS AND DEPARTURES

R	N	PNW	M	S	C	Hg	Hl
36	74	.30	38.23	21.91	192.48		R
34	167	.35	34.96	25.22	187.28	*	*
33	123	.36	32.54	19.50	185.30	R	
32	50	.42	26.14	14.99	178.87	R	

Column headings in this table are the same as those used in Table I.

* The flow rate of 34 per hour could not be resolved. That is, the hypothesis that the true mean was greater than 36 could not be rejected, even with the large number of data points obtained. In view of the large sample variance at this level, and the closeness of the sample mean to 36, it was decided to abandon this flow rate and be satisfied with knowing that the flow rate just below it was under capacity, while the one above it was over capacity.

The flow rate of 35 per hour is omitted because it could not be represented by an integer number of time units of 5 seconds width.

VIII. CONCLUSIONS

It was concluded that under existing FAA traffic separation rules, the capacity of the terminal was a peak flow rate of 22 aircraft per hour. Under the revised separation requirements of 2 miles between arrivals and 1 mile between an arrival and a departure, a peak flow of 33 aircraft per hour can be handled.

There is a significant advantage to be gained from allowing the closer spacing. It would certainly be worth while to carefully examine the separation rules to be applied. It is too expensive in terms of lost capacity to require unnecessary distance between aircraft.

The capacity figures resulting from this solution are considerably more pessimistic than those used in the Boeing study. Their assumptions resulted in a much more disciplined arrival rule than the Poisson process assumed here. In fact, they assumed that the aircraft arrived at the Initial Approach Fix already properly spaced for the approach [2]. As a result, they were able to sustain a flow rate of 28 aircraft per hour under existing rules, and a flow rate of 41 aircraft per hour under the 2 mile - 1 mile rules.

IX. MODEL DESCRIPTION

The model was designed to represent the specific scenario of a STOL terminal operating in the environment of an intra-urban rapid transit system. As a result, the following assumptions are built into the model and cannot be changed without re-writing the program.

1. The model considered traffic to be homogenious. In this case, homogenious applies both to the aircraft type involved and to the method of operation. All aircraft are considered under positive radar control and operating under instrument flight rules (IFR).

2. The terminal modeled has a single runway with a single approach course from the holding pattern to the runway.

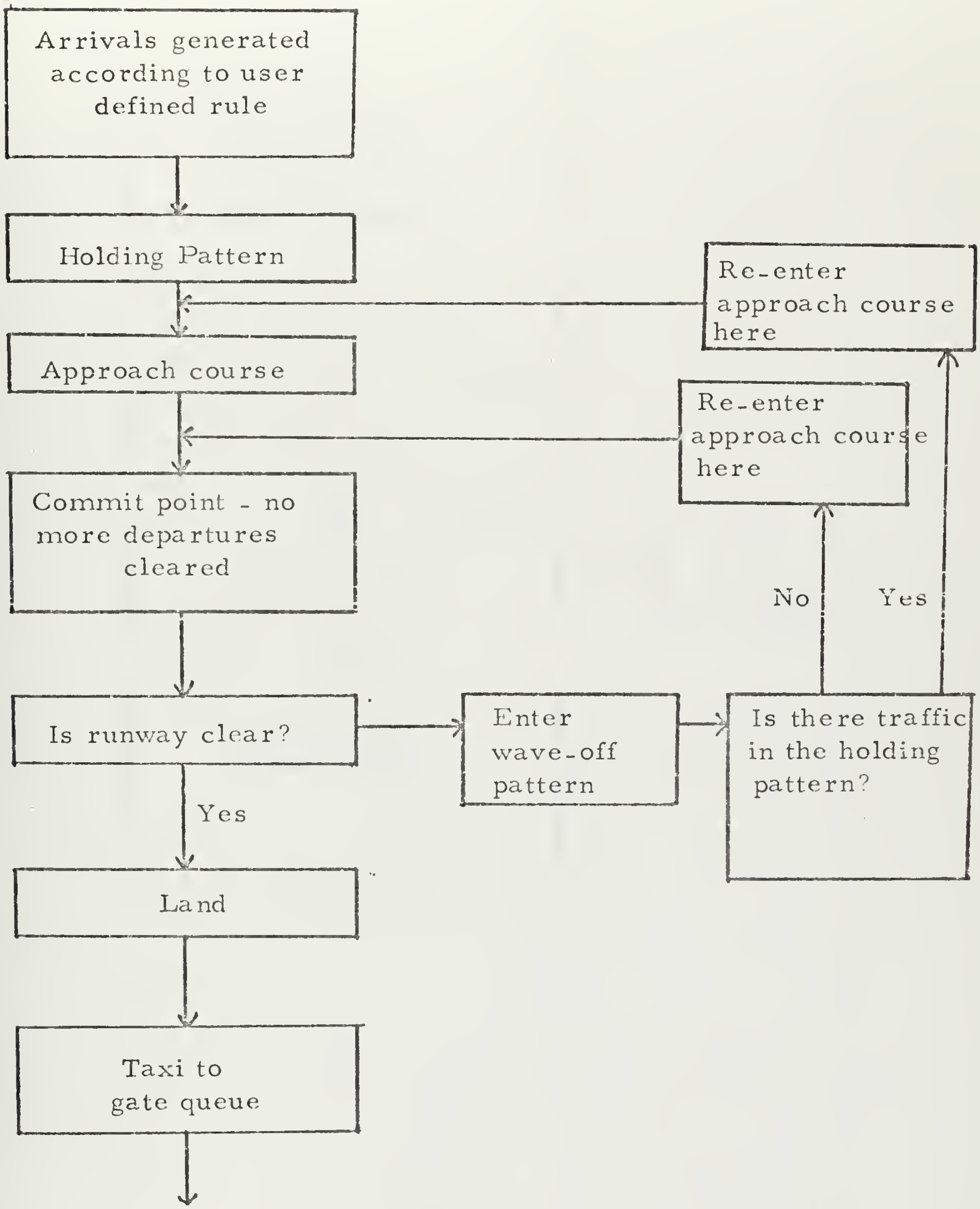
3. The holding pattern is at the initial approach fix (IAF).

4. All queues are of the first-in-first-out type.

5. Arrivals are given priority over departures.

6. Aircraft that have had to go around on an approach are given priority for another approach over other aircraft in the holding pattern.

The traffic flow in the model is as indicated in Figure 2. Figure 3 shows the physical system that is modeled.



(continued on following page)

FIGURE 2. TRAFFIC FLOW

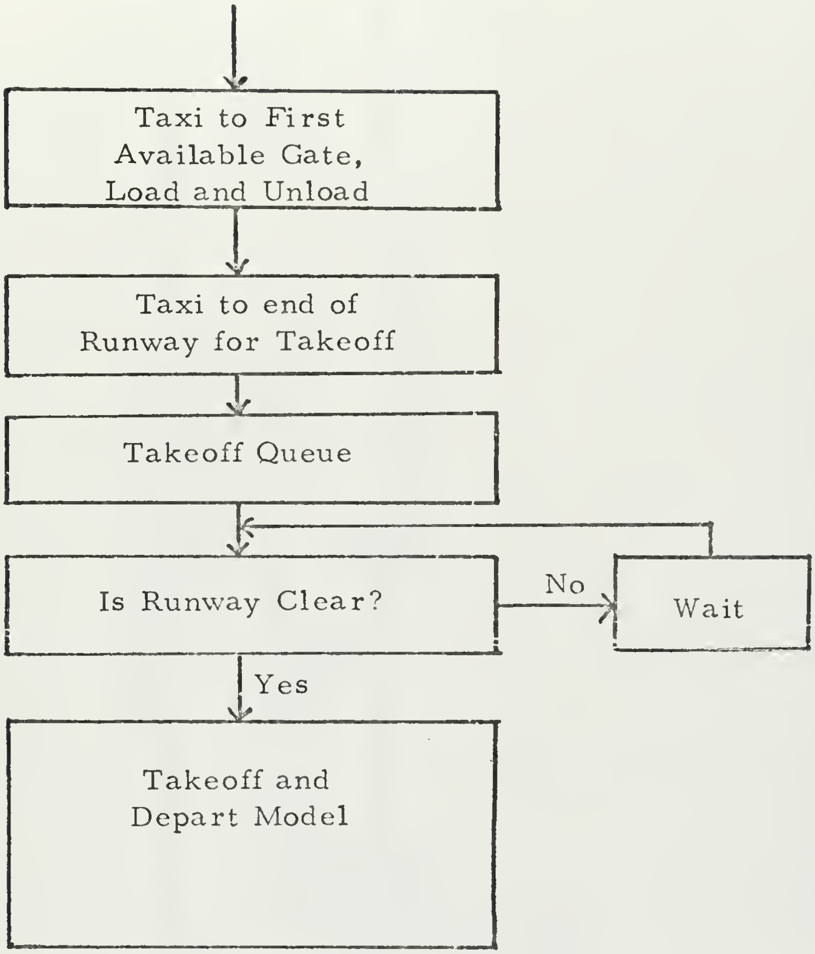


FIGURE 2. (continued)

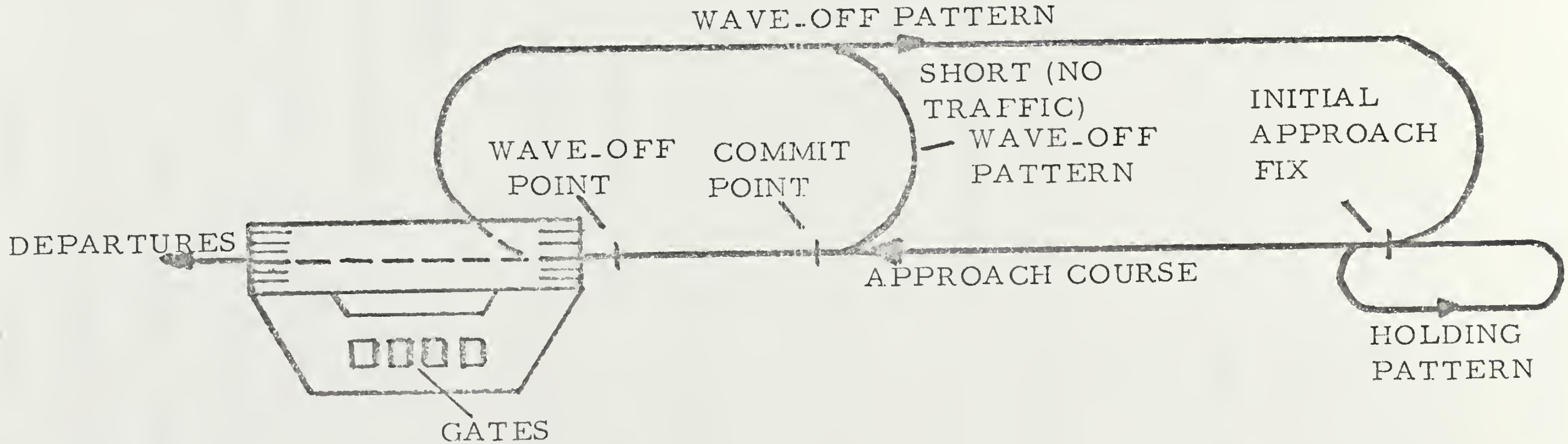


FIGURE 3. TYPICAL STOL TERMINAL ASSUMED

X. THE GPSS PROGRAM

The simulation was written using General Purpose Simulation System (GPSS). This system generates entities and moves them through a sequence of queues and facilities according to user defined rules. It uses abstract time units to measure flow rates and delay times.

A. GPSS ANALOGIES

The analogies that are used in the GPSS model are as follows:

1. Queue 1 represents the holding pattern, queue 3 the gate queue, and queue 4 the takeoff queue.

2. Facility 1 represents the approach course, facility 2 the runway, and facility 21 the runway threshold.

3. Storage 1 represents the passenger gates, with the storage capacity determining the number of gates to be simulated.

4. Each GPSS entity represents an aircraft in the system.

B. GPSS FUNCTIONS

In order to use the model, one must have a basic knowledge of GPSS functions since they are used to describe transit and delay time probability distributions. To define a function, the user must input a set of ordered pairs to the GPSS program. The program interprets the first number of each ordered pair as the independent variable, and the second as the dependent variable. The entire function is approximated by linear interpolation between the points described.

The GPSS program generates a uniform random variate on the interval 0 to 1 (or 0 to 1000) to 3 significant figures. By using this number as the independent variable, a function value is obtained from the user defined function. This value is then multiplied by the mean of the distribution in question to get a realization from the distribution. In other words, the function defined represents a mapping from a uniform distribution to the desired cumulative probability distribution, normalized so that its mean is 1.

The exact mechanics and form for inputting the ordered pairs will be described in section XII.

C. GPSS OUTPUT

The GPSS output is organized into sections as follows: (the reader may find it helpful to refer to the GPSS output from the sample run in Appendix B).

1. Source listing of the GPSS deck. In this listing each operational card is assigned a block number and each card in the program is assigned a card number by the compiler. It will be noted that these program assigned numbers bear no relation to the card numbers punched in columns 78-80 of the source deck.

2. A partially compiled source listing (this listing is omitted in Appendix B).

3. The flow summary. This is the first of the statistical output data from the run. This summary is a count of the total number of

entities that have moved through each block, as well as the number that were present in the block at the end of the run. Note that if statistics are kept from other than the start of the run, the total shown for each block is summed only over the time for which statistics were kept.

4. The runway utilization statistics. Three values are shown here. The average utilization is computed as the proportion of time the runway was occupied. The number of entries is a count of the number of operations, takeoffs and landings, that occurred on the runway. The average time per transaction is the average time each runway operation took, in GPSS time units.

5. The runway threshold utilization statistics. The data in this section is computed in the same manner as the runway utilization statistics.

6. The gate statistics. The capacity simply indicates the number of gates that were simulated. The average contents shows the average number of aircraft that were at the gates. The average utilization is the proportion of available gate time that was used. The average time per transaction is computed as the average time an aircraft remained at the gate, in GPSS time units. The current contents and maximum contents are self explanatory.

7. The queue statistics. These are self explanatory except for the zero entity concept. A zero entity is one which did not have to wait in the queue, but simply passed through. The $AVERAGE TIME/TRANS column shows the average time each entity had to wait in the queue, not counting zero entities.

8. Table of transit times. This is a tabulation of the total time each aircraft took to transit the model, in GPSS time units. The table structure, that is the range and increment size, is user defined. The overflow portion of the table includes all values greater than the table upper bound. All intervals in the table have as their lower bound the upper bound of the previous interval. The first interval has zero as its lower bound.

XI. THE FORTRAN PROGRAM

The FORTRAN section of the model is used solely as a pre-processor to convert input data to a form acceptable to the GPSS program. It accepts inputs in a convenient form and units, such as MPH, miles and ft/sec^2. It outputs printed output for the information of the user, and punched output to be included in the GPSS deck.

A. FORTRAN INPUTS

All inputs to the FORTRAN program are on punched cards. Appendix B shows a sample input deck. Inputs fall into two types, required and optional. Naturally, all required inputs must be assigned values for each run. The normal FORTRAN convention relating to variable types has been followed, all variables are real (decimal) numbers except those whose names start with the letters I, J, K, L, M, N, or O. Input variables which are real numbers must have a decimal point supplied, even if the value assigned is a whole number. Integer variables must not have decimal points included.

The first character of each card of the input deck must be punched starting in column 2, while the last character on each card must be before column 72. The first characters on card 1 of the input deck must be an ampersand followed by the word INPUT, followed by at least one blank.

A variable is assigned a value by punching the variable name, an equal sign, its value and a comma. An example is: ARRT=5.3, . After the last comma on the last card, an ampersand followed by the word END must be punched.

As many cards as are necessary may be used. Spacing between variables is unimportant. The last character on all cards except the last must be a comma. That is, a variable definition must not be split between two cards.

If a vector variable is involved, the entire vector may be input by naming it and then listing as many values as there are vector elements. An example of a vector variable is NFLAG which contains 6 elements and is an integer variable. It may be input by punching NFLAG=3, 3, 3, 4, 1, 0, which sets NFLAG(1) to 3, NFLAG(2) to 3, etc. The same result may be obtained by punching NFLAG(1)=3, NFLAG(2)=3, etc., or NFLAG=3*3, 4, 1, 0, where "3*3" is equivalent to 3, 3, 3.

1. <u>Required Inputs</u>

The following named variables are required inputs to the FORTRAN program.

APPD	Distance in miles from the initial approach fix to the landing touchdown point.
APPSPD	The mean approach speed of the aircraft, in MPH.
ARRT	The initial mean time interval, in minutes, between arrivals at the holding pattern.

AVGATE	The mean time required to load and unload passengers, measured in minutes.
DIST	The number of miles of separation required between consecutive aircraft on the approach course.
LUPPER	The upper limit for the table of transit times, units are time units.
LOWER	The lower limit for the table of transit times in time units.
LINC	The number of time units in each tabular interval in the table of transit times.
NGATES	The number of passenger gates available in the terminal.
RUN	The amount of time, in time units, to be simulated. Statistics are kept for this time period unless a value for STDY is specified (see Optional Input section for STDY).
SPACE	The number of miles of separation that is required between an arrival and a departure.
TDSPD	The mean aircraft landing speed, in MPH.
TIMEU	The number of seconds to be represented by each time unit.
WDIST	The number of miles that must be traveled on a go-around to re-enter the approach course at the initial approach fix.

WOFFD The minimum distance, in miles from the touchdown point that a wave off can be safely initiated.

2. Optional Inputs

The following named variables are optional inputs to the FORTRAN program. The variables for which a default value is listed will be set to that default value if the user does not assign a value to them.

ACCEL The acceleration rate on takeoff, measured in ft/sec^2. The default value is 10 ft/sec^2.

NFLAG A six element vector used to flag options in specifying probability distributions. Three values are meaningful; 1, 2, and 3. The default value is 1. This variable is used to set up options for the following variables: ARRT, APPSPD, TDSPD, AVGATE, TAXIIN, and TAXIOU. The preceding list is ordered, i.e. NFLAG (1) refers to ARRT, NFLAG (2) to APPSPD, etc. Each time the simulation needs a value to use for one of these parameters (the actual inter arrival time between two aircraft, for example) it realizes a value from a probability distribution according to the following rules: If NFLAG is 1 (or default) a single value is realized with probability one. This value is the mean value, as input. If NFLAG is 2, a uniform distribution is sampled. If NFLAG is 3, a user specified distribution is sampled.

AMODIF — A six element vector used with NFLAG. If the corresponding NFLAG value is 1, AMODIF is ignored. If the corresponding NFLAG value is 2, the parent variable value (ARRT, APPSPD, TDSPD, etc.) is considered the mean, and the AMODIF value is half the range of the uniform distribution. That is, the distribution range is the mean $\pm$ AMODIF. If the corresponding NFLAG value is 3, the AMODIF value is the number of points the user wishes to specify to define the function the simulation will use. The user then must supply the required number of function points to the GPSS program. To realize a value, the number assigned to the parent variable will be multiplied by the function value obtained.

TACCEL — The program normally computes the time to accelerate to takeoff speed on the basis of a constant acceleration at rate ACCEL from a standing start to landing speed. If this model is not satisfactory to the user, the number of time units required to accelerate can be input here.

CHANGE — The option exists to change the mean interarrival time periodically during the simulation. If this option is to be used, the number of time units between changes in mean interarrival time is input here. Note that RUN divided by CHANGE should result in a whole number.

DECEL	The deceleration rate after landing, measured in ft/sec^2. The default value is 10 ft/sec^2.
IFR	This is a flag used to indicate that inclement weather is to be simulated. A value of 1 indicates this option is to be used. The result is the increasing of landing roll out by a factor of 1.1. A zero indicates noninclement weather is to be simulated. The default value is zero.
NPUNCH	The logical value which is assigned to the unit to process punched output. The default value is 7, the normal IBM 360/67 punch code.
NWRITE	The logical value which is assigned to the unit to process printed output. The default value is 6, the normal IBM 360/67 printer code.
NPFLAG	This is a flag on aircraft transit time. A 1 specifies that each aircraft transit time is to be printed and tabulated. A zero specifies tabulation only. The default value is zero. This option should be used with caution. Each aircraft transit time printed out will result in three lines of output. This can easily lead to a large volume of paper.
STDY	The option exists to keep statistics from other than the start of the run. Assigning a number to this variable specifies the number of time units from

the beginning of the run at which statistics will be started.

TAXIIN	The mean number of minutes required to taxi from the runway to the passenger gate. The default is 2.0 minutes.
TAXIOU	The mean number of minutes required to taxi from the passenger gates to the end of the runway. The default value is 2.0 minutes.
TDCEL	The number of time units necessary to decelerate to taxi speed after landing. The default computes the time using a model of constant deceleration from landing speed to TURNOF (see below) at a rate of DECEL.
TURNOF	The speed in MPH at which the aircraft can turn off the runway after landing and deceleration. The default value is 10 MPH.
WINDD	The wind direction relative to the runway heading, measured in degrees from zero to 180. The default value is zero.
WINDS	The wind speed in MPH. The default value is zero.

B. FORTRAN VARIABLES

The following list contains the principle FORTRAN variables and the rules and quantities used to compute them.

Variable formats are required for some outputs. The vectors which are used to contain these formats are: FMT, BLANK, SFMT, DIGIT, DIGIS, STG, TAB, TABR, FNCTS and Z1 through Z15.

HWIND	The computed headwind component.
GSPEED	The mean ground speed. It is computed by subtracting the headwind component from the mean approach speed.
COMIT	The time before an arrival lands after which no more departures can be cleared ahead of him. It is computed by dividing the minimum allowable spacing between arrivals and departures by the mean ground speed.
ATIME	The mean time required for an approach. It is obtained by dividing the approach distance by the mean ground speed.
IHX(1)	The initial mean interarrival time converted to time units.
IXH(2)	The mean time needed to obtain the required interarrival spacing on the approach course.
IXH(3)	The mean time required to travel from the holding pattern to the commit point. The commit point is determined from the COMIT computation above.
IXH(4)	The mean time required to travel from the commit point to the runway threshold.

IXH(5)	The mean time needed to travel from the threshold to the touchdown point.
IXH(6)	The time required to clear the runway after landing. It is computed by adding 5 seconds to the time required to decelerate after landing.
IXH(7)	The mean time required to taxi from the runway to the gate.
IXH(8)	The mean gate time.
IXH(9)	The mean time needed to taxi to the runway from the gate.
IXH(10)	The time needed to taxi from the end of the taxi way to position on the runway for takeoff.
IXH(11)	The time required to accelerate and takeoff.
IXH(12)	The time required to travel back to the start of the approach if a go-around is required.
IXH(13)	The time from which statistics are to be kept if other than from time zero.
IXH(14)	A flag to indicate if variable mean interarrival time is to be used.
IXH(15)	The mean interarrival time change interval. It is set equal to CHANGE.
IXH(16)	The number of gates to be simulated.
CHANGE	The time intervals at which changes in interarrival time are to be made.

IC The number of times the mean interarrival time is to be changed, if this option is used. It is computed by dividing RUN by CHANGE and subtracting 1 from the product.

The program uses two subroutines called "FITIT" and "FUNCTS". These do format fitting and no other computations.

C. FORTRAN OUTPUT

Appendix B contains a sample of the FORTRAN output. The printed output consists of two types, informational and directive.

The informational output gives the user a record of what the program has done. The first output produced is a copy of the values of all input variables. Some optional inputs which were not assigned values by the user may show negative values. This is normal and should not concern the user. The program will print a copy of all punched cards produced.

The program will check all 6 NFLAG values and their corresponding AMODIF values. If an NFLAG is specified 2 or 3, and no AMODIF value is assigned, the NFLAG will be set to 1. All NFLAG values after the check is made will be printed.

The directive output consists of instructions to supply data to the GPSS program. The data required will be a specified number of function points. All information is to be on punched cards. The program will specify the placement of the punched cards as "following card _____" where the blank will contain a card number. The card numbers referred to are punched in columns 77-80 of the GPSS deck.

XII. PROCEDURES FOR GPSS RUN

This section contains the procedures the user should follow between the FORTRAN run and the GPSS run, as well as some general remarks about the programs.

A set of function points will be required for each user supplied probability function to be used (each NFLAG set to 3), and for mean inter-arrival time changes. For probability functions, the first number of the ordered pair specifying the function point is the independent variable. This will be realized from a uniform distribution. The range of the uniform distribution will be 0 to 1 for arrival rate, landing speed, gate time, taxi in time, and taxi out time. It will be 0 to 1000 for approach speed. The second number of the ordered pair is the value of the dependent variable at the function point which is being described.

For mean interarrival time changes, the first number of each pair is an integer from 1 to IC (RUN/CHANGE -1). The second number is the mean interarrival time for that time period.

Appendix B contains some examples of function definition cards included in the GPSS deck. All of these cards are punched starting in column 1 and not past column 72, with no imbedded blanks. As many cards as are necessary may be used. Ordered pairs are separated by the character /, and the numbers in each pair are separated by a comma. The last pair on each card is not followed by the character /. Decimal

points may be omitted for whole numbers. The pairs must be ordered among themselves so that the independent variable is monotone increasing. An example would be; 1,2.31/1.1,5/1.11,10.4/2,0.03.

The FORTRAN program will produce punched output which is to be included in the basic GPSS source deck. The cards will have numbers punched in columns 77-80 which indicate their relative position in the GPSS deck. If a like numbered card already exists in the basic GPSS deck, it is to be replaced by the new card. Otherwise, the new card is to be placed in the deck in numerical order. Gaps can be expected in the card numbering system. The GPSS deck should be restored to its original basic configuration as listed in Appendix A, before another run is set up.

The GPSS program will produce the same sequence of random numbers for each run. To obtain a different sequence of random numbers, a card punched starting in column 8 with the word RMULT, and punched starting in column 19 with 2 commas and a number, may be included in the GPSS deck. The number must be a seven digit or smaller, odd number, and will be the seed value for the GPSS random number generator. This card should be placed immediately following the SIMULATE card at the head of the GPSS deck. A different sequence of random numbers will be produced for each different RMULT number used.

APPENDIX A

SOURCE LISTINGS

FORTRAN SOURCE LISTING

```
      IMPLICIT REAL*8 (Z)
      REAL*8 FMT(42),BLANK,SFMT(42),DIGIT(6),DIGIS(6),STG(4)
      REAL*8 TAB(7),TABR(5),FNCTS(8)
      DIMENSION IXH(16),NFLAG(6),AMODIF(6),FM(21)
      COMMON/PN/NPUNCH,NWRITE,NREAD
      DATA BLANK/8H        /
      DATA STG/8H(5X,9H1 ,8HSTORAGE ,8HI5,T79,2,8HH70     )/
       DATA      SFMT/8H(7X,7HIN,8HITIAL,4X,8H,4HXH1,,,3HI1,,8H5H/XH2,,,3
     1HI1,,8H5H/XH3,,,3HI1,,8H5H/XH4,,,3HI1,,8H5H/XH5,,,3HI1,,8H5H/XH6,,
     2,3HI1,,8H5H/XH7,,,3HI1,,8HT79,2H80,8H/7X,7HIN,8HITIAL,4X,8H,4HXH8,
     3,,3HI1,,8H5H/XH9,,,3HI1,,8H6H/XH10,,4H,I1,,8H6H/XH11,,4H,I1,,8H6H/
     4XH12,,4H,I1,,8H6H/XH13,,4H,I1,,8H6H/XH14,,4H,I1,,8HT79,2H85,8H/7X,
     57HIN,8HITIAL,4X,8H,5HXH15,,4H,I1,,7H         ,4H     ,8HT79,2H90,1H)/
      DATA DIGIS/8H  I2,    ,8H  I3,    ,8H  I4,    ,8H  ,I2,  ,8H  ,I3,  ,
     18H  ,I4,  /
      DATA Z1/8H,5HXH13,/,Z2/8H,I1,T78,/,Z3/8H,I2,T78,/,Z4/8H,I3,T78,/,Z
     15/8H,I4,T78,/,Z6/8H,I5,T78,/,Z7/8H(24H SHI/,Z8/8HFT FUNCT/,Z9/8HIO
     2N   XH/,Z10/8H16,C,    /,Z11/8HI1,T79, /,Z12/8HI2,T79, /,Z13/8HI6,T
     379,2/,Z14/8H2H30)    /,Z15/8H3H670)  /
      DATA FNCTS/8H(22H FXH,8H2  FUNCT,8HION    P3,8H,C   ,I1,,8HT79,2H40,
     18H)       ,8H,C   ,I2,,8H,C   ,I3,/
      DATA WINDD/0./,WINDS/0./,IFR/0/,TAXIIN/2./,TAXIOU/2./,TPOSIT/.25/,
     1ACCEL/10./,DECEL/10./,CHANGE/-1./,STDY/-1./,K2/1/,TURNOF/10./,NFLA
     2G/6*1/,AMODIF/6*-1./,TACCEL/-1./,TDCEL/-1./,NPFLAG/0/
      NAMELIST/INPUT/ACCEL,APPD,APPSPD,ARRT,AVGATE,CHANGE,DECEL,DIST,IFR
     1,LINC,LLOWER,LUPPER,       NFLAG,NGATES,NPUNCH,NWRITE,NPFLAG,RUN,SP
     2ACE,STDY,TACCEL,TAXIIN,TAXIOU,TDCEL,TDSPD,TIMEU,TPOSIT,TURNOF,WDIS
     3T,WINDD,WINDS,WOFFD,AMODIF
      NPUNCH=7
      NWRITE=6
      NREAD=5
      READ(NREAD,INPUT)
      WRITE(NWRITE,1000)
 1000 FORMAT(1H1)
      WRITE(NWRITE,INPUT)
      DO 10 I=1,42
   10 FMT(I)=BLANK
      DO 20 I=1,6
   20 DIGIT(I)=BLANK
      DO 30 I=1,42
   30 FMT(I)=SFMT(I)
      DO 40 I=1,6
   40 DIGIT(I)=DIGIS(I)
      TIMEU=60./TIMEU
      STIMEU=TIMEU*60.
      WINDD=WINDD*.1745329E-01
```

```
      HWIND=COS(WINDD)*WINDS
      TURNOF=TURNOF*528./360.
      GSPEED=APPSPD-HWIND
      IXH(1)=ARRT*TIMEU+.5
      FIXH2=DIST/GSPEED
      COMIT=(SPACE-WOFFD)/GSPEED
      ATIME=APPD/GSPEED
      IXH(3)=STIMEU*(ATIME-FIXH2-COMIT)+.5
      IXH(2)=FIXH2*STIMEU+.5
      IXH(4)=STIMEU*COMIT+.5
      IXH(5)=STIMEU*WOFFD/GSPEED+.5
      IF(IXH(5).LT.1)IXH(5)=1
      RFSPD=(TDSPD-HWIND)*528./360.
      IF(TDCEL.LT.0.)TDCEL=( RFSPD-14.)*TIMEU/(DECEL*60.)
      IF(TACCEL.LT.0)TACCEL= RFSPD*TIMEU/(ACCEL*60.)
      IF(IFR.EQ.1)TDCEL=TDCEL*1.1
      IXH(6)=TDCEL+(.083*TIMEU)+.5
      IXH(7)=TAXIIN*TIMEU+.5
      IXH(8)=AVGATE*TIMEU+.5
      IXH(9)=TAXIOU*TIMEU+.5
      IXH(10)=TPOSIT*TIMEU+.5
      IXH(11)=TACCEL+.5
      IXH(12)=STIMEU*WDIST/APPSPD-IXH(2)+.5
      IF(STDY.LT.0.)GO TO 50
      GO TO 60
50    STDY=RUN
      K2=0
60    IXH(13)=STDY
      INXH13=RUN-STDY
      IF(CHANGE.LT.0.)CHANGE=RUN
      IC=RUN/CHANGE-1.
      IXH(14)=2
      IF(IC.EQ.0)IXH(14)=1
      IXH(15)=CHANGE+.5
      IXH(16)=NGATES
      IF(IXH(4).GT.IXH(10)+IXH(11))GO TO 65
      IDEL=IXH(10)+IXH(11)+1-IXH(4)
      IXH(4)=IXH(4)+IDEL
      IXH(3)=IXH(3)-IDEL
65    J=1
      K=7
      IS=2
      IN=2
      IEX=0
      CALL FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      J=8
      K=9
      IS=5
```

```
      CALL FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      J=10
      K=13
      IEX=3
      CALL FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      J=15
      K=15
      IS=8
      CALL FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      WRITE(NPUNCH,FMT)(IXH(I),I=1,15)
      WRITE(NWRITE,9000)
      WRITE(NWRITE,FMT)(IXH(I),I=1,15)
      IF(K2.EQ.1)GO TO 70
2000  FORMAT('0    STATISTICS TO BE KEPT FROM TIME ZERO.')
      WRITE(NWRITE,2000)
      GO TO 100
70    DO 80 I=3,42
80    FMT(I)=BLANK
      FMT(3)=Z1
      FMT(4)=Z2
      FMT(5)=Z15
      DO 90 I=1,6
90    DIGIT(I)=BLANK
      DIGIT(1)=Z3
      DIGIT(2)=Z4
      DIGIT(3)=Z5
      DIGIT(4)=Z6
      J=13
      K=13
      IS=4
      IN=0
      IXH(13)=INXH13
      IEX=0
      CALL FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      WRITE(NPUNCH,FMT)INXH13
      WRITE(NWRITE,9000)
      WRITE(NWRITE,FMT)INXH13
      WRITE(NWRITE,2008)
      WRITE(NPUNCH,2008)
2008  FORMAT(7X,'RESET',T78,'660'/7X,'START',6X,'1,NP',T78,'650'/7X,'STA
     1RT',6X,'1',T40,'RESTART',T78,'690')
100   IF(IC.EQ.0) GO TO 120
      DO 110 I=1,42
110   FMT(I)=BLANK
      FMT(1)=Z7
      FMT(2)=Z8
      FMT(3)=Z9
      FMT(4)=Z10
```

```
      FMT(5)=Z11
      FMT(6)=Z14
      IF(IC.GT.9)FMT(5)=Z12
      WRITE(NWRITE,2010)IC
 2010 FORMAT(1H0,10X,'VARIABLE MEAN ARRIVAL RATE SPECIFIED. PUT IN',I3,'
     1 ORDERED PAIRS FOLLOWING CARD 30. VALUES IN TIME UNITS')
      WRITE(NWRITE,9000)
      WRITE(NWRITE,FMT)IC
      WRITE(NPUNCH,FMT)IC
      WRITE(NWRITE,2050)
      WRITE(NPUNCH,2050)
 2050 FORMAT(                                    '          1 VARIABLE    FN$
     1SHIFT',T40,'GENERATE NEW MEAN RATE',T78,'620'/7X,'SAVEVALUE   1,V1,
     2H',T40,'APPLY NEW MEAN RATE',T78,'630')
      WRITE(NWRITE,9000)
  120 IF(IXH(16).GT. 9)STG(3)=Z13
      WRITE(NWRITE,STG)IXH(16)
      WRITE(NPUNCH,STG)IXH(16)
      ITST=IXH(12)-IXH(3)*2-IXH(2)*2
      WRITE(NWRITE,9000)
      IF(ITST.GT.0)GO TO 125
      WRITE(NWRITE,2070)
      WRITE(NPUNCH,2070)
 2070 FORMAT(' SHORT ADVANCE     0,0',18X,'NO TRAFFIC WAVE OFF PATTERN',1
     11X,'543')
      GO TO 126
  125 WRITE(NWRITE,2080)
      WRITE(NPUNCH,2080)
 2080 FORMAT(' SHORT ADVANCE     V2,0',T40,'NO TRAFFIC WAVE OFF PATTERN',
     1T78,'543')
      DATA TAB/8H(5X,'1 ',8H,5HTABLE,8H,6X,3HM1,8H,,I1,',',8H, I1,',',8H
     1,I1,T79,,8H2H75 )  /,TABR/8H,,I2,',',8H,I3,T79,,8H,I2,T79,,8H, I2,
     2',',8H,,I3,',' /
  126 NTAB=(LUPPER-LLOWER)/LINC+2
      IF(LLOWER.GT.9)TAB(4)=TABR(1)
      IF(LLOWER.GT.99)TAB(4)=TABR(5)
      IF(LINC.GT.9)TAB(5)=TABR(4)
      IF(NTAB.GT.9)TAB(6)=TABR(3)
      IF(NTAB.GT.99)TAB(6)=TABR(2)
      WRITE(NWRITE,9000)
      WRITE(NWRITE,TAB)LLOWER,LINC,NTAB
      WRITE(NPUNCH,TAB)LLOWER,LINC,NTAB
      DO 130 I=1,6
  130 IF(AMODIF(I).LT.0)NFLAG(I)=1
      WRITE(NWRITE,2900) NFLAG
 2900 FORMAT('0 OPTIONAL FUNCTION FLAGS AND MODIFIERS HAVE BEEN CHECKED
     1FOR CONSISTANCY. FLAGS ARE NOW SET AS FOLLOWS:'/'  NFLAG 1=',I2,5X
     2,'NFLAG 2=',I2,5X,'NFLAG 3=',I2,5X,'NFLAG 4=',I2,5X,'NFLAG 5=',I2,
```

```
      35X,'NFLAG 6=',I2)
       ITSFR=NFLAG(1)
       MODIF=AMODIF(1)
       GO TO(150,140),ITSFR
       WRITE(NPUNCH,3000)
       WRITE(NWRITE,9000)
       WRITE(NWRITE,3000)
 3000  FORMAT(7X,'GENERATE    XH1,FN$POIS,,,1',6X,'GENERATE ARRIVALS',T78,
      1'100')
       WRITE(NWRITE,3100)MODIF
 3100  FORMAT(1H0,T10,'FUNCTION OPTION SPECIFIED FOR INTER-ARRIVAL TIMES.
      1 PUT IN',I3,' ORDERED PAIRS FOLLOWING CARD 20')
       CALL FUNCT(1,MODIF,    2)
       GO TO 151
  140  WRITE(NWRITE,3200)AMODIF(1)
 3200  FORMAT(1H0,T10,'UNIFORM DISTRIBUTION FOR INTER-ARRIVAL TIMES SPECI
      1FIED WITH SPREAD OF + OR-',F6.2,' MINUTES')
       MODIF  =AMODIF(1)*TIMEU+.5
       CALL FUNCT(1,MODIF,    1)
       GO TO 151
  150  WRITE(NWRITE,3300)ARRT
 3300  FORMAT(1H0,T10,'INTER-ARRIVAL TIMES SPECIFIED DETERMINISTIC WITH O
      1NE ARRIVAL EVERY',F6.1,' MINUTES')
  151  ITSFR=NFLAG(2)
       MODIF=AMODIF(2)
       GO TO(180,170),ITSFR
  160  WRITE(NPUNCH,3400)
       WRITE(NWRITE,9000)
       WRITE(NWRITE,3400)
 3400  FORMAT(7X,'ADVANCE     XH2,FN$FXH2',T40,'APPROACH SEPARATION',T78,'
      1140'/'  FEED ADVANCE     XH3,FN$FXH2',T40,'TRAVEL TO COMMIT POINT',
      2T78,'160'/7X,'ADVANCE     XH4,FN$FXH2',T40,'TRAVEL TO WAVEOFF POINT
      3',T78,'180'/7X,'ADVANCE     XH5,FN$FXH2',T40,'TRAVEL TO THRESHOLD',
      4T78,'220')
       WRITE(NWRITE,3500)MODIF
 3500  FORMAT(1H0,T10,'FUNCTION OPTION SPECIFIED FOR APPROACH SPEED. PUT
      1IN',I3,' ORDERED PAIRS FOLLOWING CARD 40. INDEPENDENT VARIABLE'/11
      2X,'IN RANGE 0 TO 1000')
       DO 161 I=1,42
  161  FMT(I)=BLANK
       DO 162 I=1,6
  162  FMT(I)=FNCTS(I)
       IF(MODIF    .GT.9)FMT(4)=FNCTS(7)
       IF(MODIF    .GT.99)FMT(4)=FNCTS(8)
       WRITE(NWRITE,9000)
       WRITE(NWRITE,FMT) MODIF
       WRITE(NPUNCH,FMT)MODIF
       GO TO 181
```

```
 170 WRITE(NWRITE,3550)AMODIF(2)
3550 FORMAT(1H0,T10,'UNIFORM DISTRIBUTION FOR  APPRCACH SPEED SPECIFIED
    1WITH SPREAD OF + OR -',F6.2,' MPH')
     FM(1)=GSPEED/(GSPEED+AMODIF(2))
     FMODU=2.-FM(1)
     FMOD=(FMODU-FM(1))/20.
     DO 171 I=2,21
 171 FM(I)=FM(I-1)+FMOD
     WRITE(NWRITE,9000)
     WRITE(NWRITE,3400)
     WRITE(NPUNCH,3400)
     WRITE(NWRITE,3560)FM
     WRITE(NPUNCH,3560)FM
3560 FORMAT(' FXH2  FUNCTION    P3,C21',T79,'40'/'000,',F4.2,'/050,',F4.
    12,'/100,',F4.2,'/150,',F4.2,'/200,',F4.2,'/250,',F4.2,'/300,',F4.2
    2,T79,'41'/'0350,',F4.2,'/400,',F4.2,'/450,',F4.2,'/500,',F4.2,'/55
    30,',F4.2,'/600,',F4.2,'/650,',F4.2,T79,'42'/'0700,',F4.2,'/750,',F
    44.2,'/800,',F4.2,'/850,',F4.2,'/900,',F4.2,'/950,',F4.2,'/1000,',F
    54.2,T79,'43')
     GO TO 181
180  WRITE(NWRITE,3600)APPSPD
3600 FORMAT(1H0,T10,'APPROACH SPEED SPECIFIED DETERMINISTIC WITH VALUE'
    1,F6.1,' MPH')
 181 ITSFR=NFLAG(3)
     MODIF=AMODIF(3)
     GO TO(210,200),ITSFR
     WRITE(NWRITE,9000)
     WRITE(NWRITE,3700)
     WRITE(NPUNCH,3700)
3700 FORMAT(7X,'ADVANCE      XH6,FN$FXH3',T40,'ROLLOUT',T78,'250')
     WRITE(NWRITE,3800)MODIF
3800 FORMAT(1H0,T10,'FUNCTION OPTION SPECIFIED FOR TOUCHDOWN SPEED. PUT
    1 IN',I3,' ORDERED PAIRS FOLLOWING CARD 50')
     CALL FUNCT(2,MODIF,    2)
     GO TO 211
 200 WRITE(NWRITE,3900)AMODIF(3)
3900 FORMAT(1H0,T10,'UNIFORM DISTRIBUTION FOR TOUCHDOWN SPEED SPECIFIED
    1 WITH SPREAD OF + OR-',F6.2,' MPH')
     MODIF=    IXH(6)-IXH(6)*TDSPD/(TDSPD+AMODIF(3))
     CALL FUNCT(2,MODIF,    1)
     GO TO 211
 210 WRITE(NWRITE,4000)TDSPD
4000 FORMAT(1H0,T10,'TOUCHDOWN SPEED SPECIFIED DETERMINISTIC AT',F6.1,'
    1 MPH')
 211 ITSFR=NFLAG(4)
     MODIF=AMODIF(4)
     GO TO(240,230),ITSFR
     WRITE(NWRITE,9000)
```

```
      WRITE(NWRITE,4100)
      WRITE(NPUNCH,4100)
 4100 FORMAT(7X,'ADVANCE     XH7,FN$FXH4',T40,'TAXI IN',T78,'270')
      WRITE(NWRITE,4200)MODIF
 4200 FORMAT(1H0,10X,'FUNCTION OPTION SPECIFIED FOR TAXI-IN TIME. PUT IN
     1',I3,' ORDERED PAIRS FOLLOWING CARD 55')
      CALL FUNCT(3,MODIF,    2)
      GO TO 241
  230 WRITE(NWRITE,4300)AMODIF(4)
 4300 FORMAT(1H0,10X,'UNIFORM DISTRIBUTION FOR TAXI-IN TIME SPECIFIED WI
     1TH SPREAD OF + OR-',F6.2,' MINUTES')
      MODIF=  AMODIF(4)*TIMEU+.5
      CALL FUNCT(3,MODIF,    1)
      GO TO 241
  240 WRITE(NWRITE,4400)TAXIIN
 4400 FORMAT(1H0,10X,'TAXI-IN TIME SPECIFIED DETERMINISTIC AT',F6.2,' MI
     1NUTES')
  241 ITSFR=NFLAG(5)
      MODIF=AMODIF(5)
      GO TO(270,260),ITSFR
      WRITE(NWRITE,9000)
      WRITE(NWRITE,4500)
      WRITE(NPUNCH,4500)
 4500 FORMAT(7X,'ADVANCE     XH8,FN$FXH5',T40,'LOAD AND UNLOAD PAX',T78,'
     1300')
      WRITE(NWRITE,4600)MODIF
 4600 FORMAT(1H0,10X,'FUNCTION OPTION SPECIFIED FOR GATE TIME. PUT IN',I
     13,' ORDERED PAIRS FOLLOWING CARD 60')
      CALL FUNCT(4,MODIF,    2)
      GO TO 271
  260 WRITE(NWRITE,4700)AMODIF(5)
 4700 FORMAT(1H0,T10,'UNIFORM DISTRIBUTION FOR GATE TIME SPECIFIED WITH
     1SPREAD OF + OR -',F6.2,' MINUTES')
      MODIF=  AMODIF(5)*TIMEU+.5
      CALL FUNCT(4,MODIF,    1)
      GO TO 271
  270 WRITE(NWRITE,4800)AVGATE
 4800 FORMAT(1H0,T10,'GATE TIME SPECIFIED DETERMINISTIC  WITH VALUE OF',
     1F6.2,' MINUTES')
      MODIF=AMODIF(6)
  271 ITSFR=NFLAG(6)
      GO TO(300,290),ITSFR
      WRITE(NWRITE,9000)
      WRITE(NWRITE,4900)
      WRITE(NPUNCH,4900)
 4900 FORMAT(7X,'ADVANCE     XH9,FN$FXH6',T40,'TAXI OUT',T78,'330')
      WRITE(NWRITE,5000)MODIF
 5000 FORMAT(1H0,10X,'FUNCTION OPTION SPECIFIED FOR TAXI OUT TIME. PUT I
```

```
     1N',I3,' ORDERED PAIRS FOLLOWING CARD 65')
      CALL FUNCT(5,MODIF,   2)
      GO TO 301
  290 WRITE(NWRITE,5100)AMODIF(6)
 5100 FORMAT(1H0,T10,'UNIFORM DISTRIBUTION SPECIFIED FOR TAXI OUT TIME W
     1ITH SPREAD OF + OR -',F6.3,' MINUTES')
      MODIF=  AMODIF(6)*TIMEU+.5
      CALL FUNCT(5,MODIF,   1)
      GO TO 301
  300 WRITE(NWRITE,5200)TAXIOU
 5200 FORMAT(1H0,10X,'TAXI OUT TIME SPECIFIED DETERMINISTIC AT',F6.2,' M
     1INUTES')
      IF(NPFLAG.EQ.0)GO TO 301
      WRITE(NWRITE,9000)
      WRITE(NWRITE,5300)
      WRITE(NPUNCH,5300)
 5300 FORMAT(7X,'PRINT',T19,'20,20,XH,1',T40,'PRINT TOTAL TIME OF TRANSI
     1T',T78,'440')
 9000 FORMAT(1H0,7X,'THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT')
  301 STOP
      END
```

```
      SUBROUTINE FITIT(FMT,DIGIT,IXH,J,K,IS,IN,IEX)
      REAL*8 FMT(42),DIGIT(6)
      DIMENSION IXH(16)
      DO 10 I=J,K
      IEXP=1
      IF(IXH(I).LT.10)GO TO 10
    4 IDX=IXH(I)/10**IEXP
      IF(IDX)10,5,6
    5 IFMT=IS+IN*I
      IDIG=IEXP-1+IEX
      FMT(IFMT)=DIGIT(IDIG)
      GO TO 10
    6 IEXP=IEXP+1
      GO TO 4
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FUNCT(NUMBER,MODIF,N)
      REAL*8 BLANK,FMT(6),FNCT(13,5),GEN(2)
      COMMON/PN/NPUNCH,NWRITE,NREAD
      DATA GEN/8H0)      ,8H3,C  ,I3,/
      DATA BLANK/8H        /
      DATA FNCT/8H(23H POI,8HS  FUNCT,8HION    RN,8H3,C  ,I1,,8HT79,2H20,
     18H)       ,8H3,C  ,I2,,8H(7X,15HG,8HENERATE ,8H   XH1,,I,8H1,4H,,,1,
     28HT78,3H10,8H2,4H,,,1,8H(23H FXH,8H3  FUNCT,8HION    RN,8H3,C  ,I1,,
     38HT79,2H50,8H)       ,8H3,C  ,I2,,8H(7X,15HA,8HDVANCE  ,8H   XH6,,I,
     48H1,T78,3H,8H250     ),8H2,T78,3H,8H(23H FXH,8H4  FUNCT,8HION    RN,
     58H3,C  ,I1,,8HT79,2H55,8H)       ,8H3,C  ,I2,,8H(7X,15HA,8HDVANCE  ,
     68H   XH7,,I,8H1,T78,3H,8H270)     ,8H2,T78,3H,8H(23H FXH,8H5  FUNCT,
     78HION    RN,8H3,C  ,I1,,8HT79,2H60,8H)       ,8H3,C  ,I2,,8H(7X,15HA,
     88HDVANCE  ,8H   XH8,,I,8H1,T78,3H,8H300)     ,8H2,T78,3H,8H(23H FXH,
     98H6  FUNCT,8HION    RN,8H3,C  ,I1,,8HT79,2H65,8H)       ,8H3,C  ,I2,,
     18H(7X,15HA,8HDVANCE  ,8H   XH9,,I,8H1,T78,3H,8H330)     ,8H2,T78,3H/
      DO 10 I=1,6
   10 FMT(I)=BLANK
      IF(N.EQ.2)GO TO 30
      IF(MODIF.GT.99)GO TO 60
      DO 20 I=1,5
   20 FMT(I)=FNCT(I+7,NUMBER)
      IF(MODIF.GT.9)FMT(4)=FNCT(13,NUMBER)
      IF(NUMBER.EQ.1)FMT(6)=GEN(1)
      GO TO 50
   30 DO 40 I=1,6
   40 FMT(I)=FNCT(I,NUMBER)
      IF(MODIF.GT.9)FMT(4)=FNCT(7,NUMBER)
      IF(MODIF.GT.99)FMT(4)=GEN(2)
   50 WRITE(NWRITE,9000)
      WRITE(NWRITE,FMT)MODIF
      WRITE(NPUNCH,FMT)MODIF
 9000 FORMAT(1H0,7X,'THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT')
      RETURN
   60 WRITE(NWRITE,1000)NUMBER,MODIF
 1000 FORMAT(//'0  *** MODIF NUMBER ',I3,' IS TOO LARGE. ITS VALUE IS ',
     1I5,' TIME UNITS. THE PROGRAM WILL NOT HANDLE VALUES ABOVE 99 ***'/
     2'0  ***PROGRAM TERMINATED IN SUBROUTINE FUNCT ***')
      STOP
      END
```

B A S I C   G P S S   S O U R C E   L I S T I N G

```
        SIMULATE
        GENERATE    XH1,0,,,1          GENERATE ARRIVALS
        ASSIGN      3,RN3
        QUEUE       1                  APPROACH HOLDING
        SEIZE       1
        TEST E      XH30,K0
        DEPART      1
        ADVANCE     XH2,0              APPROACH SEPARATION
        RELEASE     1
FEED    ADVANCE     XH3,0              TRAVEL TO COMMIT POINT
        SAVEVALUE   31+,1,H
        ADVANCE     XH4,0              TRAVEL TO WAVEOFF POINT
        GATE NU     2,WOFF             WAVE OFF POINT
        SEIZE       2
        PREEMPT     21                 COMMIT TO LAND
        ADVANCE     XH5,0              TRAVEL TO THRESHOLD
        SAVEVALUE   31-,1,H
        RETURN      21                 TOUCHDOWN
        ADVANCE     XH6,0              ROLLOUT
        RELEASE     2                  CLEAR OF RUNWAY
        ADVANCE     XH7,0              TAXI IN
        QUEUE       3                  WAIT FOR GATE
        ENTER       1                  ENTER GATE
        DEPART      3
        ADVANCE     XH8,0              LOAD AND UNLOAD PAX
        PRIORITY    0
        LEAVE       1                  DEPART GATE
        ADVANCE     XH9,0              TAXI OUT
        QUEUE       4                  WAIT FOR TAKEOFF
        SEIZE       21                 TAXI INTO TAKEOFF POSITION
        TEST E      XH31,K0
        ADVANCE     XH10,0
        SEIZE       2                  CLEARED FOR TAKEOFF
        DEPART      4
        RELEASE     21
        ADVANCE     XH11,0             TAKEOFF
        RELEASE     2
        SAVEVALUE   20,M1,H            GATHER TOTAL TIME OF TRANSIT
        TABULATE    1                  TABULATE TOTAL TIME OF TRANSIT
        TERMINATE   0
WOFF    SAVEVALUE   31-,1,H
        GATE U      1,SHORT
        ADVANCE     XH12,0             WAVEOFF PATTERN
AIN     SAVEVALUE   30+,1,H
```

```
         ADVANCE     XH2,0
         ADVANCE     XH2,0
         SAVEVALUE   30-,1,H
         TRANSFER    ,FEED
       2 VARIABLE    XH12-XH3*2-XH2*2
  SHCRT  ADVANCE     V2,0                   NO TRAFFIC WAVE OFF PATTERN
         TRANSFER    ,AIN
C
         GENERATE    XH13,0,1               TIMER SEGMENT
         ADVANCE     1,0
  ADV    ADVANCE     XH13,0                 RUNNING TIME
         TERMINATE   1                      STOP
         GENERATE    1,0                    VARIATION OF ARRIVAL RATE
         SEIZE       3
         ADVANCE     XH15,0                 VARIATION INTERVAL
         RELEASE     3
         SAVEVALUE   16+,1,H
         TERMINATE   0
C
         REPORT
         EJECT
         SPACE       3
         SPACE       3
         SPACE       3
         SPACE       3
  BLC    TITLE       ,FLOW SUMMARY
         EJECT
         SPACE       3
         SPACE       3
         SPACE       3
         SPACE       3
         SPACE       3
  FAC    TITLE       ,RUNWAY UTILIZATION STATISTICS
  FAC    INCLUDE     F2/2,3,4
         SPACE       2
  FAC    TITLE       ,RUNWAY THRESHOLD UTILIZATION STATISTICS
  FAC    INCLUDE     F21/2,3,4
         SPACE       3
  STC    TITLE       ,GATE UTILIZATION STATISTICS
  STC    INCLUDE     S1/2,3,4,6,7,8
         SPACE       3
  QUE    TITLE       ,QUEUE STATISTICS FOR HOLDING PATTERN,GATE QUEUE AND T
TAKEOFF QUEUE, RESPECTIVELY.
  QUE    INCLUDE     Q1-Q4/1,2,3,5,7,8,10
         EJECT
         SPACE       3
         SPACE       3
         SPACE       3
```

```
         SPACE     3
         SPACE     3
TAB      TITLE     .TABLE CF TRANSIT TIMES
         END
```

APPENDIX B

The following pages show the input and output for a sample run of the model.

The first page shows the input cards that were used. Next is the FORTRAN printed output followed by the punched output.

The GPSS source output shows the function definition cards that were included as per the instructions in the FORTRAN printed output. The GPSS output has been edited to exclude the partially compiled source listing.

THE FOLLOWING INPUT CARDS WERE USED IN THE SAMPLE RUN.

```
&INPUT APPD=9.0,APPSPD=82.3,ARRT=5.45,AVGATE=3.0,DIST=2.0,LUPPER=324,
LLOWER=156,LINC=12,NGATES=3,RUN=3600.,SPACE=1.0,TDSPD=77.,TIMEU=5.0,
WDIST=13.0,WOFFD=0.1,NFLAG=3*3,1,3,1,AMODIF=23.0,2*29.0,0.,23.0,0.,
TAXIIN=1.5,TAXIOU=1.5,CHANGE=360.,STDY=1440., &END
```

```
&INPUT
ACCEL=  10.000000    ,APPD=  9.0000000    ,APPSPD=  82.299988    .ARRT=  5.4499998    .AVGATE=  3.0000000    .CHANGE=
  360.00000    ,DECEL=  10.000000    ,DIST=  2.0000000    ,IFR=              0,LINC=           12,LLOWER=          155,LUPPER=         324,
NFLAG=            3,           3,           3,           1,           3,           1,NGATES=           3,NPUNCH=           7,NWRITE=
          6,NPFLAG=           0.RUN=  3600.0000    .SPACE=  1.0000000    .STDY=  1440.0000    .TACCEL= -1.0000000    ,TAXIIN=
  1.5000000    ,TAXIOU=  1.5000000    ,TDCEL= -1.0000000    ,TDSPD=  77.000000    ,TIMEU=  5.0000000    ,TPOSIT= 0.25000000    ,
TURNOF=  10.000000    ,WDIST=  13.000000    ,WINDD= 0.0              ,WINDS= 0.0              ,WOFFD= 0.99999964E-01.AMODIF=
  23.000000    .  29.000000    .  29.000000    . 0.0         ,  23.000000    , 0.0
&END

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      INITIAL     XH1.65/XH2.17/XH3.53/XH4,8/XH5,1/XH6,3/XH7.18                      80
      INITIAL     XH8,36/XH9,18/XH10,3/XH11,2/XH12,97/XH13,1440/XH14,2              85
      INITIAL     XH15.360                                                           90

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      INITIAL     XH13,2160                                                         670
      RESET                                                                         660
      START       1,NP                                                              650
      START       1                      RESTART                                    690

          VARIABLE MEAN ARRIVAL RATE SPECIFIED. PUT IN  9 ORDERED PAIRS FOLLOWING CARD 30. VALUES IN TIME UNITS

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
SHIFT FUNCTION    XH16,C9                                                            30
    1 VARIABLE    FN$SHIFT               GENERATE NEW MEAN RATE                     620
      SAVEVALUE   1,V1,H                 APPLY NEW MEAN RATE                        630

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
    1 STORAGE     3                                                                  70

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
SHORT ADVANCE     0.0                    NO TRAFFIC WAVE OFF PATTERN                543

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
    1 TABLE       M1,156,12,16                                                       75

 OPTIONAL FUNCTION FLAGS AND MODIFIERS HAVE BEEN CHECKED FOR CONSISTANCY. FLAGS ARE NOW SET AS FOLLOWS:
 NFLAG 1= 3     NFLAG 2= 3     NFLAG 3= 3     NFLAG 4= 1     NFLAG 5= 3     NFLAG 6= 1

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      GENERATE    XH1,FN$POIS,,,1        GENERATE ARRIVALS                          100

        FUNCTION OPTION SPECIFIED FOR INTER-ARRIVAL TIMES. PUT IN 23 ORDERED PAIRS FOLLOWING CARD 20

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
POIS  FUNCTION    RN3.C23                                                            20

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      ADVANCE     XH2,FN$FXH2            APPROACH SEPARATION                        140
 FEED ADVANCE     XH3.FN$FXH2            TRAVEL TO COMMIT POINT                     160
      ADVANCE     XH4,FN$FXH2            TRAVEL TO WAVEOFF POINT                    180
      ADVANCE     XH5,FN$FXH2            TRAVEL TO THRESHOLD                        220

        FUNCTION OPTION SPECIFIED FOR APPROACH SPEED. PUT IN 29 ORDERED PAIRS FOLLOWING CARD 40. INDEPENDENT VARIABLE
          IN RANGE 0 TO 1000

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
FXH2  FUNCTION    P3,C29                                                             40

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      ADVANCE     XH6.FN$FXH3            ROLLOUT                                    250

        FUNCTION OPTION SPECIFIED FOR TOUCHDOWN SPEED. PUT IN 29 ORDERED PAIRS FOLLOWING CARD 50

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
FXH3  FUNCTION    RN3,C29                                                            50

          TAXI-IN TIME SPECIFIED DETERMINISTIC AT  1.50 MINUTES

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
      ADVANCE     XH8,FN$FXH5            LOAD AND UNLOAD PAX                        300

          FUNCTION OPTION SPECIFIED FOR GATE TIME. PUT IN 23 ORDERED PAIRS FOLLOWING CARD 60

       THE FOLLOWING LINE(S) IS A COPY OF PUNCHED OUTPUT
FXH5  FUNCTION    RN3,C23                                                            60

          TAXI OUT TIME SPECIFIED DETERMINISTIC AT  1.50 MINUTES
```

IN ADDITION TO THE PRINTED OUTPUT, THE FOLLOWING PUNCHED CARDS WERE PRODUCED BY THE FORTRAN PROGRAM.

```
        INITIAL    XH1,65/XH2,17/XH3,53/XH4,8/XH5,1/XH6,3/XH7,18                  80
        INITIAL    XH8,36/XH9,18/XH10,3/XH11,2/XH12,97/XH13,1440/XH14,2           85
        INITIAL    XH15,360                                                       90
        INITIAL    XH13,2160                                                     670
        RESET                                                                    660
        START      1,NP                                                          650
        START      1                   RESTART                                   690
  SHIFT FUNCTION   XH16,C9                                                        30
      1 VARIABLE   FN$SHIFT            GENERATE NEW MEAN RATE                    620
        SAVEVALUE  1,V1,H              APPLY NEW MEAN RATE                       630
      1 STORAGE    3                                                              70
  SHORT ADVANCE    0,0                 NO TRAFFIC WAVE OFF PATTERN               543
      1 TABLE      M1,156,12,16                                                   75
        GENERATE   XH1,FN$POIS,,,1     GENERATE ARRIVALS                         100
  POIS  FUNCTION   RN3,C23                                                        20
        ADVANCE    XH2,FN$FXH2         APPROACH SEPARATION                       140
   FEED ADVANCE    XH3,FN$FXH2         TRAVEL TO COMMIT POINT                    160
        ADVANCE    XH4,FN$FXH2         TRAVEL TO WAVEOFF POINT                   180
        ADVANCE    XH5,FN$FXH2         TRAVEL TO THRESHOLD                       220
  FXH2  FUNCTION   P3,C29                                                         40
        ADVANCE    XH6,FN$FXH3         ROLLOUT                                   250
  FXH3  FUNCTION   RN3,C29                                                        50
        ADVANCE    XH8,FN$FXH5         LOAD AND UNLOAD PAX                       300
  FXH5  FUNCTION   RN3,C23                                                        60
```

GPSS OUTPUT

```
NUMBER  *LOC   OPERATION   A,B,C,D,E,F,G                    COMMENTS
               SIMULATE
         POIS  FUNCTION    RN3,C23
        0,0/.1,.105/.2,.223/.3,.357/.4..511/.5..693/.6..916/.7.1.20/.75.1.386
        .8,1.61/.84,1.83/.88,2.12/.9,2.3/.92,2.53/.94,2.8/.95,3.0/.96,3.22
        .97,3.51/.98,3.91/.99,4.61/.995,5.3/.998,6.2/.999,6.9
        SHIFT  FUNCTICN    XH16,C9
        1,42/2,42/3,42/4,37/5,32/6,27/7,21/8,21/9,63
         FXH2  FUNCTICN    P3,C29
        6..7875/10..8028/20..8258/30..8402
        40,.8513/50,.8606/100,.8912/152,.9125
        200,.9286/251,.9431/309,.9575/352,.9677
        401,.9788/455,.9898/500,1.00/544,1.0102
        599,.1.0212/648,1.0323/692,1.0425/749,1.0569
        799.1.0714/0846.1.0875/900.1.1088/950.1.1394
        960,1.1487/970,1.1598/979,1.1742/990,1.1972
        994,1.2125
         FXH3  FUNCTION    RN3.C29
        0.0062,0.8200/0.0102,0.8330/0.0202,0.8524/0.0301,0.8646
        0.0401,0.8740/0.0505,0.8819/0.1003,0.9078/0.1515,0.9258
        0.2005,0.9395/0.2514,0.9518/0.3035,0.9640/0.3520,0.9726
        0.4013,0.9820/0.4552,0.9914/0.5000,1.0000/0.5438,1.0086
        0.5987.1.0180/0.6480.1.0274/0.6915.1.0360/0.7486.1.0482
        0.7995,1.0605/0.8455,1.0742/0.8997,1.0922/0.9495,1.1181
        0.9599,1.1260/0.9699,1.1354/0.9788,1.1476/0.9898,1.1670
        0.9938,1.1800
         FXH5  FUNCTION    RN3,C23
        0.0/.1..105/.2..223/.3..357/.4..511/.5..693/.6..916/.7,1.20/.75,1.386
        .8,1.61/.84,1.83/.88,2.12/.9,2.3/.92,2.53/.94,2.8/.95,3.0/.96,3.22
        .97,3.51/.98,3.91/.99,4.61/.995,5.3/.998,6.2/.999,6.9
            1  STORAGE     3
            1  TABLE       M1,156,12,16
               INITIAL     XH1,65/XH2,17/XH3.53/XH4.8/XH5.1/XH6.3/XH7.18
               INITIAL     XH8,36/XH9,18/XH10,3/XH11,2/XH12,97/XH13,1440/XH14,2
               INITIAL     XH15,360
 1             GENERATE    XH1.FN$POIS...1            GENERATE ARRIVALS
 2             ASSIGN      3,RN3
 3             QUEUE       1                          APPROACH HOLDING
 4             SEIZE       1
 5             TEST E      XH30,K0
 6             DEPART      1
 7             ADVANCE     XH2.FN$FXH2                APPROACH SEPARATION
 8             RELEASE     1
 9       FEED  ADVANCE     XH3,FN$FXH2                TRAVEL TO COMMIT POINT
10             SAVEVALUE   31+,1,H
11             ADVANCE     XH4,FN$FXH2                TRAVEL TO WAVEOFF PCINT
12             GATE NU     2.WOFF                     WAVE OFF POINT
13             SEIZE       2
14             PREEMPT     21                         COMMIT TO LAND
15             ADVANCE     XH5.FN$FXH2                TRAVEL TO THRESHOLD
16             SAVEVALUE   31-,1,H
17             RETURN      21                         TOUCHDOWN
18             ADVANCE     XH6,FN$FXH3                ROLLOUT
19             RELEASE     2                          CLEAR OF RUNWAY
20             ADVANCE     XH7,0                      TAXI IN
21             QUEUE       3                          WAIT FCR GATE
22             ENTER       1                          ENTER GATE
23             DEPART      3
24             ADVANCE     XH8.FN$FXH5                LOAD AND UNLOAD PAX
25             PRIORITY    0
26             LEAVE       1                          DEPART GATE
27             ADVANCE     XH9,0                      TAXI OUT
28             QUEUE       4                          WAIT FOR TAKEOFF
29             SEIZE       21                         TAXI INTO TAKEOFF PCSITION
30             TEST E      XH31.K0
31             ADVANCE     XH10,0
32             SEIZE       2                          CLEARED FOR TAKEOFF
33             DEPART      4
34             RELEASE     21
35             ADVANCE     XH11.0                     TAKEOFF
36             RELEASE     2
37             SAVEVALUE   20,M1,H                    GATHER TOTAL TIME OF TRANSIT
38             TABULATE    1                          TABULATE TOTAL TIME OF TRANSIT
39             TERMINATE   0
40       WOFF  SAVEVALUE   31-,1,H
```

```
41              GATE U       1,SHORT
42              ADVANCE      XH12,0                WAVEOFF PATTERN
43        AIN   SAVEVALUE    30+,1,H
44              ADVANCE      XH2,0
45              ADVANCE      XH2,0
46              SAVEVALUE    30-,1,H
47              TRANSFER     ,FEED
            2   VARIABLE     XH12-XH3*2-XH2*2
48        SHORT ADVANCE      0,0                   NO TRAFFIC WAVE OFF PATTERN
49              TRANSFER     ,AIN
          C
50              GENERATE     XH13,0,1              TIMER SEGMENT
51              ADVANCE      1,0
52        ADV   ADVANCE      XH13.0                RUNNING TIME
53              TERMINATE    1                     STOP
54              GENERATE     1,0                   VARIATION OF ARRIVAL RATE
55              SEIZE        3
56              ADVANCE      XH15,0                VARIATION INTERVAL
57              RELEASE      3
58              SAVEVALUE    16+,1,H
            1   VARIABLE     FN$SHIFT              GENERATE NEW MEAN RATE
59              SAVEVALUE    1,V1,H                APPLY NEW MEAN RATE
60              TERMINATE    C
          C
                START        1,NP
                RESET
                INITIAL      XH13,2160
                START        1                     RESTART
                REPORT
                EJECT
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
          BLO   TITLE        ,FLOW SUMMARY
                EJECT
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
          FAC   TITLE        ,RUNWAY UTILIZATION STATISTICS
          FAC   INCLUDE      F2/2,3,4
                SPACE        2
          FAC   TITLE        ,RUNWAY THRESHOLD UTILIZATION STATISTICS
          FAC   INCLUDE      F21/2,3,4
                SPACE        3
          STO   TITLE        ,GATE UTILIZATION STATISTICS
          STO   INCLUDE      S1/2,3,4,6,7,8
                SPACE        3
          QUE   TITLE        ,QUEUE STATISTICS FOR HOLDING PATTERN,GATE QUEUE AND T
         TAKEOFF QUEUE, RESPECTIVELY.
          QUE   INCLUDE      Q1-Q4/1,2,3,5.7.8.10
                EJECT
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
                SPACE        3
          TAB   TITLE        ,TABLE OF TRANSIT TIMES
                END
```

FLOW SUMMARY
BLOCK COUNTS

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
1	0	66	11	0	71	21	0	67	31	0	68	41	0	5
2	0	66	12	0	72	22	0	67	32	0	68	42	0	4
3	0	66	13	0	67	23	0	67	33	0	68	43	0	5
4	0	66	14	0	67	24	0	67	34	0	68	44	0	5
5	0	66	15	0	67	25	0	67	35	0	68	45	0	5
6	0	66	16	0	67	26	0	67	36	0	68	46	0	5
7	0	66	17	0	67	27	0	67	37	0	68	47	0	5
8	0	67	18	0	67	28	0	68	38	0	68	48	0	1
9	1	72	19	0	67	29	0	68	39	0	68	49	0	1
10	0	71	20	0	67	30	0	68	40	0	5	50	0	1

BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL	BLOCK	CURRENT	TOTAL
51	0	1												
52	1	2												
53	0	1												
54	0	6												
55	0	6												
56	1	6												
57	0	6												
58	0	6												
59	0	6												
60	0	6												

RUNWAY UTILIZATION STATISTICS

AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN
.158	135	2.533

RUNWAY THRESHOLD UTILIZATION STATISTICS

AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN
.154	135	2.466

GATE UTILIZATION STATISTICS

CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
3	1.187	.395	38.268		3

QUEUE STATISTICS FOR HOLDING PATTERN,GATE QUEUE AND TAKEOFF QUEUE, RESPECTIVELY.

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	ZERO ENTRIES	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	CURRENT CONTENTS
1	5	.708	28	23.181	40.263	
3	1	.001	66	.044	3.000	
4	2	.152		4.838	4.838	

TABLE OF TRANSIT TIMES

TABLE 1
ENTRIES IN TABLE 68 | MEAN ARGUMENT 195.294 | STANDARD DEVIATION 58.687 | SUM OF ARGUMENTS 13280.000 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
156	22	32.35	32.3	67.6	.798	-.669
168	6	8.82	41.1	58.8	.860	-.465
180	7	10.29	51.4	48.5	.921	-.260
192	2	2.94	54.4	45.5	.983	-.056
204	5	7.35	61.7	38.2	1.044	.148
216	6	8.82	70.5	29.4	1.106	.352
228	3	4.41	74.9	25.0	1.167	.557
240	5	7.35	82.3	17.6	1.228	.761
252	4	5.88	88.2	11.7	1.290	.966
264	1	1.47	89.7	10.2	1.351	1.170
276	1	1.47	91.1	8.8	1.413	1.375
288	1	1.47	92.6	7.3	1.474	1.579
300	1	1.47	94.1	5.8	1.536	1.784
312	0	.00	94.1	5.8	1.597	1.988
324	0	.00	94.1	5.8	1.659	2.193
OVERFLOW	4	5.88	100.0	.0		
AVERAGE VALUE OF OVERFLOW		356.25				

END

LIST OF REFERENCES

1. Drake, H. M., Kenyon, G. C., and Galloway, T. L.; "An Extremely Short Haul Urban Aircraft System", NASA Working Paper MA-69-1, May 1969.

2. The Boeing Company, Seattle, Washington; "Study of Aircraft in Intra-Urban Transportation Systems: San Francisco Bay Area"; Final report prepared for NASA contract NAS2-5969, April 1971.

3. Geoffrion, D. R., Kirbardin, V. M.; "Statistical Presentation of Operational Landing Parameters for Transport Jet Airplanes"; FAA Flight Standards Service Release No. 470, June 1962.

4. Rallis, Tom; Capacity of Transport Centres; Ports, Railway Stations, Road Haulage Centres, and Airports; Technical University of Denmark, Copenhagen, 1967.

5. Hooten, E. N., Galliher, H. P., Warskow, M. A., Grossman, K. G.; "Operational Evaluation of Airport Runway Design and Capacity"; Airborne Instruments Laboratory, prepared for FAA project No. 412-7-IR, Report No. 7601-6, January, 1968.

6. Hooten, E. N., Burns, H., Warskow, H. P.; "Operational Development of Techniques for Computing Airport Capacity"; Airborne Instruments Laboratory, prepared for FAA project No. 430-003-02E. Report No. RD-68-20, June, 1969.

7. Lindgren, B. W.; Statistical Theory; The Macmillan Company, New York, 1962. Pages 255-257.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Chief of Naval Personnel Pers 11b Department of the Navy Washington, D. C. 20370	1
4.	Department of Operations Research and Administrative Sciences, Code 55 Naval Postgraduate School Monterey, California 93940	1
5.	Assoc. Professor A. F. Andrus, Code 55As Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
6.	Professor D. E. Harrison, Code 61Hx Physics Department Naval Postgraduate School Monterey, California 93940	1
7.	LT Robert E. Rinker, USN 16091 Sharon Lane Salinas, California 93901	1
8.	National Aeronautics and Space Administration Advanced Concepts and Missions Division Moffett Field, California 94035 Attn: Mr. George C. Kenyon	1

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

RIGINATING ACTIVITY (Corporate author) aval Postgraduate School Ionterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

EPORT TITLE

etermination of STOL Air Terminal Traffic Capacity Through Use of omputer Simulation

DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Iaster's Thesis; September 1971

UTHOR(S) (First name, middle initial, last name)

obert E. Rinker

EPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
eptember 1971	69	7

CONTRACT OR GRANT NO. PROJECT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

DISTRIBUTION STATEMENT

pproved for public release; distribution unlimited.

SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

ABSTRACT

The capacity of an air terminal for Short Takeoff and Landing aircraft is nalyzed. The terminal is considered to be operating as part of an intra-urban ir rapid transit system. The air traffic flow through the terminal is modeled y a computer simulation written in both the FORTRAN IV and GPSS languages. he model is used to solve the traffic capacity problem under two sets of traffic ontrol rules. In the first case, existing FAA rules, which require 3 miles eparation between arrivals and 2 miles between an arrival and a departure, re used. In a second case, the rules are 2 miles between arrivals and 1 nile between an arrival and a departure. A detailed description of the model s presented so that others might use the model.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
rt capacity						
ation						
uter simulation						
transit						
OL						

Thesis
R5717 Rinker 130783
c.1
Determination of
STOL air terminal
traffic capacity
through use of com-
puter simulation.